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SAFEGUARDING ELECTRICAL EQUIPMENT USED IN GASSY MINES

EUROPEAN PRACTICE: III GERMANY

BY

L. C. ILSLEY

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SAFEGUARDING ELECTRICAL EQUIPMENT USED IN GASSY MINES [1]
EUROPEAN PRACTICE: III - GERMANY

By L. C. Ilsley[2]

Cooperation between the United States Bureau of Mines and the Safety in Mines Research Board of Great Britain, continuous since 1924, has made possible this and other papers on safety subjects. Grateful acknowledgment is made to representatives of the Board for their assistance in arranging visits to several mine safety stations, and to F. R. Wynne, Deputy Chief Inspector of Mines, for arranging visits to mines in Great Britain and other countries in Europe.

During the summer of 1927 the writer had the privilege of visiting the mine safety testing stations in great Britain, Belgium, Germany, and France, in the order named. All of these countries have large coal mines, many of which are rated as gassy. Therefore, when the installation of electrical equipment is contemplated, each of these countries is confronted with the same safety problem as is the United States - the development of electrical equipment that will not ignite gassy atmospheres which through neglect or accident might surround the equipment. The means employed by these countries in safeguarding gassy mines should therefore be of general interest to safety engineers in American coal mines, and it is proposed to give a brief survey for each of the four countries mentioned. The third of these surveys covers conditions in Germany.

GERMAN PIONEER RESEARCHES

Any attempt to survey the subject of explosion-proof equipment from an international standpoint should include a review of the pioneer work done by Germany in investigating the possibility of using electrical equipment in gassy mines and in outlining conditions under which such equipment might safely be introduced. The permissibility work connected with the investigation of electrical motors carried on by the United States Bureau of Mines has been influenced by the pioneer work of Dr. Beyling. His report,[3] an illustrated treatise of 89 printed pages, was translated and has been used as a reference work.

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2 Electrical engineer, U. S. Bureau of Mines.

3 Beyling, C., Versuche zwecks Erprobung der Schlagwettersicherheit besonders geschetzter elecktrischer Motoren und Apparate sowie zur Ermittlung geeigneter Schutzvorrichtungen fur solche Betriebsmittel. Ausgefuhrt auf der berggewerkschaftlichen Versuchstrecke in Gelsenkirchen, 1906, 89 pp. Zeitschrift Glückauf, Essen, Jahrgang 1906, Parts No. 1-13.

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Review of Beyling's Report

A report of the early research work conducted by Beyling was published during 1906 and is divided by him into three sections, as follows:

1. Experiments of the year 1903, in which tests were made using apparatus submitted by the electrical companies.

2. Experiments of the year 1904, in which tests were more of a research nature, involving the finding of a suitable means of protecting electrical motors and apparatus and testing different experimental devices.

3. Experiments of the year 1905, in which tests were made of motors having incorporated within them protective devices that had given promise in the experiments made during the preceding year.

The tests made during the first year showed the inadequacy of existing designs and the necessity for much experimental work.

The tests made during the second year are especially interesting to manufacturers who are designing or testing permissible-type equipment, in that nearly every conceivable scheme of protection was tried out during that year's experimental work. The tests covered the completely closed casing, wire-gauze-protected casing, the labyrinth casing, the casing with pipe protection, the flanged casing, the plate-protected casing, and the oil-filled casing.

The conclusions with respect to the various types of protection are of interest in that so many of them still hold good after 25 years' experience with the explosion-proof type of equipment. A free rendering of the more pertinent conclusions follows:

Specific Notes

Totally enclosed compartment.- The totally enclosed casing for electric motors and apparatus offers a few special advantages. The fire damp can not so easily reach the protected and dangerous parts, as a longer interval of time is required for this purpose; the danger of an outside ignition is decreased thereby, particularly in the event of a sudden occurrence of large quantities of fire damp. The casing is also very resistant to external damage - that is, to fall of rocks or rough treatment. Finally, it protects the enclosed parts against moisture and dust. Against these advantages there is the disadvantage of lack of ventilation. Even if one or several holes were made therein, or if other openings were provided, the discharge openings, in order to be safe, have to be so small that no ventilation in the proper sense of the work takes place. If, therefore, one wishes to protect the coils of motors and of transformers and the resistances of starting and of regulating devices by means of closed casings, one must reckon with a considerable drop in the efficiency

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of this apparatus, owing to poor ventilation. Therefore, these apparatus must have greater dimensions than would otherwise be necessary under the same circumstances; the initial cost and the cost of operation are thus increased. In order to obviate this undesirable feature, a different method of protection from fire damp is needed - that is, one that allows the heat to escape from the protected parts. If one rejects oil protection, there remains, for the attainment of this object, only a ventilated casing; that is to say, the protected space must communicate with the outside air through larger openings. But in order that the flame of a fire damp ignition occurring within this space should not communicate itself to the outside gases, care must be taken that the gases cool off sufficiently prior to their escape. The cooling can be accomplished in different ways. Such casings form a contrast to the totally enclosed casing in that the protective action of the totally enclosed casing is based on the fact that the hot combustion gases of a fire-damp explosion are retained in the casing as far as possible whereas the gases can escape from the casings with other protective devices after having been rendered harmless.

Gauze-protected compartments.- The experiments show that the wire-gauze-protected casing can be used to protect electric motors and apparatus against the danger of fire damp, if no intense ventilation prevails in the enclosed space. If such ventilation is present one must reckon with an intense afterburning which may lead to outside ignitions. The ventilation caused by rotation is especially harmful when the gauzes are near to or form part of the revolving portions.

The widespread view that wire gauze, which is an excellent protecting device for mine lamps, can also be used as a safeguard for electric motors and apparatus has not been corroborated to the full extent by the experiments made therewith, but, on the contrary, the wire-gauze casing presents some difficulties and does not always afford safety. Moreover, the gauzes may be easily damaged by external causes and become dangerous. In view of these defects an endeavor has been made to find another more adequate casing which possesses the advantage of the wire-gauze-protected casing - namely the ventilation of the enclosed space - without being beset by its drawbacks. Since ventilation was desired, only such casings were considered as provided communication from the interior to the exterior of the housings through large openings; the task was to provide some method of cooling the escaping gases other than that provided by the cooling action of wire gauze.

Labyrinth protection.[a]- The labyrinth casing does not seem to be suitable for the protection of electric motors and apparatus. Besides, it does not allow any appreciable ventilation of the enclosed space, owing to the smallness of the passage and the resistance met with by the cooling air on passing through the plates.

Flange-protected casings (slightly separated joints).[a]- The flange-protected casing (having an air-gap between two wide flanges) has no practical value for the protection of electric motors and apparatus, because it does not allow any appreciable ventilation of the enclosed space. The observations however, made on the occasion of the tests performed with this protective device, were of great usefulness for the further tests which aimed at finding a suitable substitute for the wire-gauze-protected casing.

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a The conclusions under headings "Labyrinth Protection" and "Flange-protected casings (slightly separated joints)" should be considered only from the objective of the experiments, which was to find a compartment which would give considerable ventilation and pressure relief. Both of these types of protection are used quite extensively in Germany.

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Plate-protected casings.- The plate-protected casing should be a substitute for the wire-gauze-protected casing. It shares its advantages without being beset by its drawbacks; for this reason a short comparison between the two seems advantageous.

There is a certain agreement between the two casings in their action. In both the ignited gases can escape in a finely subdivided condition through narrow openings and must flow along metallic walls which give them an opportunity to cool off. The advantage of the plate-protected casing consists in the fact that the mass of the heat-absorbing body is much larger, and that the discharged gases must remain in contact therewith for a longer time than in the case of the wire-gauze-protected casing. In consequence thereof it still affords safety if the pressure and hance the velocity of the hot gases is high and the absorption of the cooling body is very large. But since beginning at a certain pressure the cooling action is supplemented or replaced by other factors, the safety of the plate protection is therefore unlimited, whereas the wire-gauze enclosure fails at a certain pressure which varies with the number of layers.

The other drawbacks of gauze-protected casing either do not exist or are present to a slight extent in the plate-protected casing. Afterburning occurs seldom and is of short duration. Its consequences are therefore less to be feared; it can not cause incandescence and excessive heating of the protecting metallic plates. The plate protection is much better safeguarded against external damage by its greater mechanical strength; in good designs, even small punctures, which may occur through injury to the wire-gauze, are impossible. For this reason, the plate-protected casing requires less supervision.

The most essential advantage of the wire-gauze-protected casing, the attainment of good ventilation, can also be obtained by the plate-protected casing. The plate protection must of course have larger dimensions if the ventilation is not promoted by artificial means.

As in the wire-gauze protection, excessive openings proved to be dangerous in the plate protection also, inasmuch as the protection depends on the cooling effect. An increase of 1 millimeter in a single slit was enough to bring about outside ignitions. Therefore, if such devices are to be practicable, great care must be taken in their manufacture. If the device is equipped with but a small number of plates, notice must be taken that a high pressure is capable of arising within the casing. Hence the casing walls must receive a corresponding thickness. The strengthening of the casing walls is also required on account of the high pressure which may arise in consequence of subdivisions of the enclosed space or in consequence of rotation. In order to prevent, as far as can be done, the occurrence of a high pressure in the casing, the discharge opening should be made as large as possible. In addition to the arrangement of numerous plates, this is attained by enlarging the inside diameter of the plates to the greatest extent allowable.

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The plate-protected casing affords absolute safety if the plates are not more than 0.5 millimeter (0.02 inches) apart, if the width of the flanges amounts to 50 millimeters (1.97 inches), the thickness to 0.5 millimeter (0.02 inches), and if all the parts of the casing have such dimensions as to be capable of resisting high pressures.

The safety of plate protection is independent of the content of the enclosed space; of the magnitude of the total discharge opening, which in its turn is conditioned by the number of slits and the magnitude of the inside diameter of each plate; of the position of the ignition point; and of the composition of the fire damp mixture.

The larger the total discharge opening in comparison with the enclosed space the greater is the effective cooling action of the plate protection and the smaller is the pressure arising in the casing.

Openings in the casing, if larger than the slits, are dangerous.

The afterburning of the fire damp seldom occurs, and has a long duration only when the enclosed space is ventilated artifically with great intensity. The safety of the casing is not harmed thereby.

By means of the plate protection one may obtain a practical, useful and absolutely explosion-proof casing for electric motors and apparatus. With further improvement and test of this protective device, one could consider the problem, which was proposed at the beginning of the fundamental tests, as solved.

General Conslusions

Beyling's report closes with a set of conclusions based not only upon the experiments made using various types of experimental protective devices, but also upon later tests made with motors and other apparatus equipped with protective devices built as a result of the earlier experiments. These final conclusions, though rather extended, are so much to the point that it has seemed best to quote them in their entirety:

Various Types of Casing Discussed.--Of the various protective devices for electric motors and apparatus which had been subjected to a detailed test, the labyrinth, the pipe, and the flange-protected casing, proved to be insufficient or unsuitable. The following have been found useful on the basis of the tests: The closed casing, the wire-gauze-protected casing, the plate-protected casing, and the oil-filled casing.

The totally enclosed casing can be used only for apparatus that does not become considerably heated and does not require, therefore, any ventilation of the enclosed space. As it must be made very resistant to explosion pressures, it is heavy, but it offers the advantage of being very resistant to external injury.

The wire-gauze-protected casing allows very good ventilation of the enclosed space; it is cheap and light. The mechanical resistance of the wire-gauze area is very small, and the consequences of afterburning are harmful in the case of artificial ventilation.

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The plate-protected casing likewise gives the possibility of ventilating the protected parts; but such ventilation, in the absence of an artificial one, requires large dimensions of the protected device and hence entails a higher cost than in the case of the wire-gauze protection. Its mechanical resistance, however, is incomparably greater, and its safety is not endangered by afterburning.

The oil-filled casing does not allow the mine gases any access to the sparking parts, and therefore affords the best protection. Its field of applicability is limited, however.

The most important deductions from the tests with regard to the practical construction of these casings, and those which must therefore be taken into consideration in the construction of explosion-proof motors or apparatus, are as follows:

Details covering construction.- For all casings except the oil-filled casing too great subdivision of the enclosed space, and particularly the use of several larger spaces connected by constricted passages, are to be avoided. Care should be taken lest such connections be made through the oil chambers of motor bearings.

The joints between the various parts of the casing, as well as the surfaces of contact of lids, doors, covers, etc. should be built in the form of wide, smooth flanges.

It is not advisable to use rubber, asbestos, or other such material for gaskets. If, however, gaskets are used, they must be placed in such a way that they will not be driven out by the high pressure arising within the casing.

Shafts and spindles should traverse the casing wall through long metallic bearings (50 millimeters, if possible) (1.97 inches) which in turn should be solidly connected with the protecting casing.

The same holds for the passage of connection cables; the lead entrances should be sealed with insulating compound. Rubber bushings should be avoided.

Hollow shafts should be filled with insulating compound.

All screws should be so secured that they do not become loosened in operation and thus give rise to through-holes.

In the completely closed casing all parts should be able to resist a pressure of 8 atmospheres. Holes for the release of pressure should be avoided.

In the wire-gauze-protected casing standard, flame-safety lamp wire-gauze with 144 meshes per square centimeter and wire 0.35 millimeter (0.014 inch) in diameter should be used. Wire-gauze with a larger width of the meshes or smaller thickness of the wire should be avoided.

The wire gauze should be made of bronze or zinc-coated steel.

It must be uniform, free from flaws, and clean.

The total protecting gauze area (the sum of all superposed gauze areas) should be at least 150 square centimeters per liter (658 square inches per cubic foot) of gas content of the enclosed space.

The wire gauze should consist of at least two layers.

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The distance between the gauzes should not be less than 5 millimeters (0.20 inches) and not more than 20 millimeters (0.79 inches).

Larger gauze areas should be provided with reinforcement.

The wire gauze should be arranged as a removable part to allow easy inspection and replacement of gauze.

All openings in the casing should be carefully avoided.

The gauze areas should be so placed that the afterburning flames do not strike the gauze, and so that combustible substances can not fall upon them.

The wire gauze should not be fastened by means of soldering. It should preferably be stretched in substantial frames or similar devices and bolted securely.

The wire gauze should be protected against external damage by perforated plates or similar means.

Plate-protected casings.- In the plate-protected casing the annular metallic plates should have flanges 50 millimeters (1.97 inches) wide and by 0.5 millimeter (0.02 inch) thick and should be so arranged through the insertion of suitable spacers that the maximum separation (width of slit) between them does not exceed 0.5 millimeter (0.02 inch).

The assembling of the plates should be done very carefully. No slit should be wider than 0.5 millimeter (0.02 inch).

The material used should be bronze, brass, tin-coated steel, or zinc-coated steel.

All open holes should be avoided. The interior of the enclosed space should be connected with the outside air only through the slits between the plates.

To avoid excessive internal pressure, the number of the plates (slits) and the inside diameter of the plates should be made as large as possible.

If the total discharge opening is made small in comparison with the gas content of the casing, then all the parts of the casing should be strong enough to be capable of withstanding a pressure of several atmospheres.

The plate assembly should be placed in removable parts so as to make convenient inspection and replacement of plates possible.

The plate assembly should be protected against external injury by a cover.

Oil-filled casings.- The oil casing must be liberally enough dimensioned that escape of sparks above the oil level is prevented.

The required height of the oil level should be determined by the manufacturer by means of a practical test and indicated by him by a special mark.

The height of the oil level should be evident without opening the casing.

Contacts or other current-carrying parts which are immersed in oil must be such as not to cause an intensive decomposition or gasification of the oil when the circuit is closed or opened.

The casing should be made in such a way that the sparking parts are not laid bare in consequence of excessive movement of the oil.

If the escaping of the sparks from the oil can not be prevented, then the oil box itself should be enclosed according to the principles of a closed casing.

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These points should serve to indicate how the casings are to be made in order that the particular protective devices on which their safety is based should be efficient.

General consideration.- In addition to this, there are a number of construction devices which contribute to increasing safety in other ways. Such, for instance, are the interlocks designed to allow the opening of the protected casings only when the spark-producing parts are cut out of the circuit. A similar precaution requires the use of lead seals, so that only specially authorized, qualified persons can open the casings. To prevent short-circuit sparks, care should be taken that no bare wires or terminals should be placed outside of the casing. The casing should be made strong enough so as not to be broken by falling rocks.

The casing should not be made too small. For the smallness of the enclosed space hardly contributes toward increasing the protection against fire damp, it renders difficult the exchanging of brushes and the access to any other enclosed parts. The casings should also be provided with solid and tight glass windows which will allow the interior to be observed without opening the casing.[b]

In actual operation, the protected casings should be maintained in the condition which conduces to their safety. Particularly the wire-gauze-protected casing requires close supervision. The gauzes should be kept clean and should be inspected frequently. In the oil-filled casing the height of the oil level should be observed regularly; care should also be taken to have suitable oil. The plate protection should be protected against dangerous changes by its inherent strength; nevertheless, dust and moisture should be removed as much as possible. The closed casing requires the least attention.

Selection of casing for specific service.- Finally, let us discuss briefly the question as to what kind of casing is to be selected for each electric apparatus.

Small motors such as those used for drilling machines and small coal-cutting machines should be equipped with a totally enclosed casing. They are also protected thereby against the adverse external conditions to which they are exposed.

In the case of larger motors, such as those used for driving auxiliary ventilating fans, larger coal-cutting machines, portable air compressors, auxiliary pumps, and hoists, it is advisable as a rule to enclose the windings and, in particular, the sparking parts.

For the latter are more likely to cause ignition of fire damp than the coils; they can also be more easily protected against fire damp because they do not need any ventilation. The closed casings are suitable for the protection of motors up to a certain size. Beyond this the wire-gauze or the plate-protected casings are to be preferred because they are lighter. For the frame of the motor, it is best to use the plate protections.

b Observation windows are no longer used. The windows referred to here mean the gauge glasses for oil-filled casings.

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In the mine workings proper, motors up to 30 horsepower together with the apparatus belonging thereto, are commonly used. As these are the most exposed to the danger of fire damp, especial attention has been paid in our tests to the consideration of equipping such apparatus with explosion-proof casings. But the protective devices which have been discussed can also be used for motors up to 50 horsepower.

Still larger motors are used principally for pumps, hoists, larger fans, and compressors and are installed near the downcast shafts or near underground places that receive fresh air. It is therefore hardly necessary to equip these motors with an explosion-proof casing. If, however, such a protection is desired, it will undoubtedly be sufficient to protect the sparking parts; this can be done by means of the wire-gauze-and-plate protection. The enclosing of the windings of very large motors would meet with considerable difficulties. It is not necessary, however, because the ignition of the fire damp through the windings is almost out of the question. In the first place the motor is situated in the fresh air current; it could not, therefore, be surrounded by mine gases except in the case of an extraordinary disturbance; even then the windings would have to be injured at the exact instant this unusual accident occurred. Such a coincidence of events need not be provided for.

For apparatus that does not require any ventilation, such as switches and fuses, it is best to use the closed or the oil-filled casing. The contacts of starting and regulating resistances should be protected by a closed casing. Resistances which must dissipate heat may be immersed in oil in the case of starting resistances, but regulating resistances should preferably be ventilated by wire-gauze or plate protection.

As a rule, the oil-filled casing will be sufficient for transformers.

So far as the danger of igniting fire damp by electric motors and apparatus is concerned, there are no longer any difficulties in the way of completely utilizing the great advantages offered by the electric power transmission for underground work, particularly in the mine workings proper. Thus, despite the many initial failures, the object aimed at has finally been attained by means of tedious and often dangerous tests.

GERMAN REGULATIONS FOR THE CONSTRUCTION OF FIREDAMP-PROOF ELECTRIC MACHINES AND APPARATUS

The regulations of 1926 cover the essential requirements which electrical equipment had to meet at the time the visit was made. These requirements are included among other electrical regulations in a booklet[4] prepared by Dr. C. L. Weber and published by Julius Springer of Berlin. A free rendering of these regulations follows:

> Regulations for the Construction of Firedamp-Proof Protective Devices in Electrical Machines, Transformers, and Apparatus. (Effective January 1, 1926.)

[4] Weber, C. L., Erläuterungen zu den Vorschriften für Errichtung und Betrieb von Starkstromanlagen einschl. Bergwerksvorschriften. Published by Julius Springer of Berlin, 1927.

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Paragraph 1. All machines, transformers, and apparatus which are intended for use in gaseous places in mines must meet the existing regulations, rules, and standards[c] of the Association of German Electrical Engineers, as far as is not otherwise stated in the exceptions which follows.[d]

Paragraph 2. All parts of electrical machines and apparatus, which give rise to sparking in normal operation, must be enclosed in firedamp-proof casings. The following casings are considered firedamp-proof

(In addition to the classes described in (A), (B), and (C), wire-gauze enclosures used as in the Davy safety lamp were permissible up to this time. These enclosures do not protect machines, etc., because the wire gauze may get dirty or be destroyed by blows or by rusting. Gauzes have therefore been abandoned.)

(A) Sealed compartments.- Totally enclosed compartments must meet the following requirements:

1. In the case of machines or apparatus having an air capacity greate than 1 liter, all parts of the enclosure must be designed for a pressure of 8 atmospheres above atmospheric pressure; those having a small air capacity for a pressure of 3 atmospheres above atmospheric pressure;[e] subdivisions o the enclosed space which are connected by small openings and therefore may be subjected to excessive pressures should be avoided.[f]

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c In addition to these construction rules the following should be noted: Rules for the design and testing of electric machines, R.E.M./1923; Rules for Rating and test of transformers, R.E.T./1923; Explanatory notes on the construction and testing of alternating current high-tension apparatus for 1,500 volts nominal voltage and upward; Rules for the construction, testing and use of switching apparatus for up to 500 volts alternating current and 3,000 volt direct current, R.E.S./1928; Regulations for insulated circuits in power installations 1926; Regulations for the construction and testing of installation material, 1926.

d For the scope of electrical operation in mining see Phillippi, ETZ, 1925 p. 997; and Glückauf, 1925, p. 807. The permissibility of specific types of applications, machines, and apparatus is determined by the mines officials (see par. 12).

e The above specified resistance to pressure is not required in the sense that the specified pressure must be withstood continuously during operations, so that an air-tight seal would be required; but the enclosure must withstand a sudden pressure caused by an explosion without being broken or having its fastenings torn.

f The air gap between the stator and rotor does not act as a small opening because of its considerable total area.

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2. The joints of those parts of compartments and housings fitting against each other, as well as the joints of lids, doors, and covers, must be formed by broad smoothly machined flanges.[g] Gaskets are preferably avoided; in case they are used, they must be applied in such a manner that they can not be pushed out by the force of an explosion. Gaskets of rubber, asbestos, and similar perishable material are not permitted.[h] Screws, rivets, etc., used to fasten on such covers must not pass through the walls of the housing but must end in bottomed holes.[i] The fastenings of the lids must be so secured that they can not loosen in operation and can only be opened with special appliances.[j]

3. Shafts and spindles shall be carried through the casing walls in long metal busings firmly attached to the housing.[k] Lead entrances must be so sealed that they will safely withstand the pressure of the explosion.

(B) Plate-protected casings.- Plate protection functions because the gases forced out after an internal ignition by the resulting expansion are cooled to so low a temperature in passing through the plates that the ignition can not be transmitted to the outside. On ignition, the internal pressure can not become so great as in totally enclosed compartments. Still, one must count on a certain pressure, and therefore sufficient strength of housing parts and their safe assembly must be provided. This is especially emphasized by the ruling under section B3. Plate protection is especially suitable for machines and apparatus of large internal volume - for storage battery boxes, for example. Plate protection consists of arranging stacks of metal plates in openings in the housing; the plates are maintained at definite intervals by spacers.

Plate-protected casings must conform to the following requirements:

1. The metal plates must be at least 50 millimeters (1.97 inches) wide and 0.5 millimeter (0.02 inch) thick; they must be so fixed by suitable spacers that the intervals do not exceed 0.5 millimeter (0.02 inch) and can not be increased by bending of the plates.[l] Plates subject to rust are not permissible.[m]

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g The width of flanges for closely fitting surfaces can be less than for those not closely fitted. In the first case 8 millimeters is regarded as the minimum width, in the second case 8 millimeters for spaces up to the 1 liter, and 25 millimeters for greater spaces.

h Care must be taken to prevent the pushed-out packing from opening up a broad crack through which an explosion occurring inside of the enclosure can be transmitted to the outside. As is explained in note e of paragraph 1, an air-tight enclosure is not required. Narrow cracks (slits) can act as a relief for the pressure of explosions, but like the plate protection must prevent the transmission of ignitions to the outside of the compartment.

i The omission of a screw shall not cause a through-hole in the wall of the enclosure.

j The "special appliance" shall not be accessible or available to every miner, but only to authorized persons. The device must therefore be, for example, a special key. (Lead seals are not sufficient.)

k Hollow shafts passing through the housing walls must have their bores suitably sealed.

l The metal of the plates must have sufficient rigidity, and individual slits should not be too long. The total area of all the slits must be as large as possible.

m Zinc-free aluminum bronze is, for instance, nonrusting material.

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2. The plate assembly must be protected from external injury, and must be so assembled that it can be removed only with special appliances.

3. The conditions of (A), sections 2 and 3, must be fulfilled. Long continued high pressure can not take place with plate protection. The conditions of (A) 2 and (A) 3 must only be considered with respect to sudden excessive pressures.

(C) Oil protection.- Oil protection consists of building the whole apparatus - with respect to those parts liable to sparking or overheating due to current - in containers filled with resin-free and acid-free mineral oil.

These containers shall be designed with an oil level so high that the occurrence of sparks above the oil level is prevented. The necessary height of the oil level must be fixed by a mark. The height of the oil level must be evident from the outside.

Paragraph 3: For portable machines, transformers, and apparatus, oil-protection is not permissible. (Those installations which are fed by a flexible conductor are considered portable; not those which at certain intervals are moved to a new place and then again are permanently connected.)

The oil protection can be built very satisfactorily; nevertheless in portable appliances rough handling as well as accidental breakage from falls of roof, etc., must be considered. Ignition resulting from breakage of the oil reservoirs is especially to be feared because of filling haulageways with smoke.

Paragraph 4: Such parts of machines, transformers, and apparatus in which sparks occur or overheating may take place only in exceptional cases are built for greater safety than is required by standard specifications and especially are safeguarded as follows:[n]

1. By a special mechanical protection of the live parts against personal contact as well as against injury and short-circuit by foreign bodies.

2. By lowering the allowable maximum temperature rise in the previously mentioned regulations, rules, and standards by 10°C.

Alternating-current induction motors require an air gap 40 to 60 per cent greater than in normal design between stator and rotor. (See D.I.N. V.D.E. 2650 and 2651.)

Paragraph 5: In a.c. motors with short-circuited rotor, joints between bars and short-circuiting ring must be brazed or some other similar safe method used.

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n Starting resistances shall be so constructed by the proper choice of materials, proper dimensions, and design that they are protected from glowing temperatures or injury under all conditions.

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Paragraph 6: Liquid rheostats are prohibited.[o] (There is no sure means of protecting liquid rheostates under all conditions from evaporation with resultant sparking.)

Paragraph 7: In the case of metallic resistances, special safety devices may be omitted if, at the same time:

1. The load on the material is so low that a dangerous rise in temperature is precluded.

2. The resistance material is rugged enough that it will not break in ordinary operation, and is firmly enough mounted that its parts can not short-circuit.

3. Foreign bodies or drops of water are prevented from falling in by a proper covering.

4. All wire connections are soldered or otherwise securely made.

Paragraph 8: All screw-fastened contacts - connection terminals of motors, resistances, etc. - which are not protected by enclosures must be so safeguarded that a loosening of the screw, resulting in poor contacts, can not occur.

Paragraph 9: Contact plugs must be constructed so that the plugs seat themselves tightly in the sockets and allow no sparks to occur while in the operating position. They must be interlocked with a firedamp-proof switch in such a manner that insertion and withdrawal of the plug is possible only when the connection is dead.

Paragraph 10: Fuse compartments must be combined and interlocked with a firedamp-proof switch in such a manner that cartridges can be taken out and replaced only when they are dead. Fuses can be used only in locked enclosures which must be made firedamp-proof to conform to Paragraph 2A, provided the plugs themselves are not firedamp-proof.[p]

Paragraph 11: Only rubber-covered cables of strong construction can be used as flexible conductors (NSH "Regulations for insulated circuits in power installations.")[q]

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o The rules for design and testing of starters, etc., limit the allowable rise in temperature. Here an especially reliable design is required.

p The opening for the tell-tales for fuses is sealed in the firedamp-proof screw plugs.

q All flexible cables used must be examined at regular intervals, and when defects are found must be immediately exchanged for entirely dependable cables. It is recommended for all gaseous mines that flexible cables be replaced after a specified period of use. In oil mines and oil shafts, rubber-covered cables without a special protective armor, are specially endangered since rubber is chemically acted upon by oil.

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Paragraph 12: Machines, transformers, and apparatus other than of the described construction are permissible if they have been shown to be firedamp-proof by special test in an authorized firedamp testing gallery.[r]

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r Also machines, etc., meeting the preceding regulations are subject to the approval of the Department of Mines. The later determines in what manner the contents of the regulations are interpreted and which designs are permitted for particular cases. These regulations are not applicable without further expansion to operations in which other gases or vapors (benzine, hydrogen, etc.) than fire damp, give rise to specific hazards. They can, however, be used as the basis for such specifications.

GERMAN EXPERIMENT STATION VISITED

On September 2, 1927, accompanied by G. Allsop of the British Safety in Mines Research Station, J. A. B. Horsley, H. M. Electrical Inspector of Mines, and Herr Stoeck, Director of C.E.A.G. Work in Dortmund, the writer had the pleasure of visiting the German Mines Experiment Station at Derne, which is only a short distance from Dortmund.

Electrical equipment, flame safety lamps, and explosives are tested at this station. The flame safety lamp station is similar to those in Belgium and the United States. The lamp-testing gallery used in the Pittsburgh station was constructed from plans obtained in Belgium.

The gallery in which motors are tested is similar to the one built for the earlier tests at the original Ruhr testing station in Gelsenkirchen.

A motor or other piece of electrical apparatus is subjected to three tests in gas (methane).

Detailed drawings are required of any equipment that is to be submitted for tests, and a great deal of attention is given to the preliminary examination of these drawings. As shown by the regulations quoted, considerable information is given as to the construction for this type of apparatus, and equipment is carefully examined to see that it comes within the limits specified. The offici gallery facilities in Great Britain, Belgium, and Germany do not appear to be so convenient as at the Pittsburgh testing station for making a large number of tests quickly.

REGULATIONS IN GERMANY AND THE UNITED STATES CONTRASTED

A study of the chief points set forth in the regulations reveals a very close agreement with the U. S. Bureau of Mines requirements for permissible equi ment. There are a few minor differences such as the permitting of gaskets betwe joints, which the German regulation allows but does not encourage; the requireme

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of special tools for renewing the fastenings to all permissible compartments, which is a step farther than American requirements have gone; and the elimination of gauze-protected compartments, which are not encouraged by the bureau.

German practice resembles the American in one respect - that trolley locomotives are allowed underground. The conditions governing their operation are much more restricted than in this country, and they are little used.

In Germany, as well as the other countries visited, alternating-current equipment predominated in the mines, whereas in American mines direct current is used largely.

In the United States some States have not as yet required permissible-motored equipment and others are very lax in their requirements, whereas in gassy mines in Germany it is understood that the following procedure is necessary:-- (1) The mine operator makes official application for permission to have a motor for a certain use. (2) The motor manufacturer must furnish a statement that the motor he is supplying is the same as the pattern that has been tested. (3) Upon the arrival at the mine the motor is dismantled and inspected by a Government inspector. (4) After the motor is installed inside the mine it is again inspected by a second Government inspector who issues special instruction regarding its use and application.

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